

**PROPERTIES OF LINEAR LOW DENSITY  
POLYETHYLENE/SILICONE RUBBER  
NANOCOMPOSITES FOR HIGH VOLTAGE  
INSULATION APPLICATION**

**NURUL HIDAYAH BINTI ISMAIL**

**UNIVERSITI SAINS MALAYSIA  
2016**

**PROPERTIES OF LINEAR LOW DENSITY POLYETHYLENE/SILICONE  
RUBBER NANOCOMPOSITES FOR HIGH VOLTAGE INSULATION  
APPLICATION**

**by**

**NURUL HIDAYAH BINTI ISMAIL**

**Thesis submitted in fulfillment of the requirements  
for the degree of  
Doctor of Philosophy**

**September 2016**

## ACKNOWLEDGEMENT

In the name of ALLAH S.W.T. the beneficent, the Merciful, who has given me patient, strength and the ability to complete this research work successfully. All perfect praises belong to ALLAH S.W.T. alone, lord of the world. May his blessing be upon Prophet Muhammad S.A.W and members of his family and companions.

The preparation of this important research would not have been possible without the support, hard work and endless efforts of a large number of individuals. First of all, I would like to express my deepest gratitude to my supervisor, Prof. Ir. Dr. Mariatti Jaafar for her continues guidance, constructive criticism, valuable suggestion and discussion, patience and advice throughout this study. I also gratefully acknowledge my co-supervisor, Prof. Hanafi Ismail for his advice in this research.

Words are not enough to express my gratitude to my beloved husband, En. Wan Nazele Wan Zain; his love, patience, sacrifice and continuous support will be remained grateful. My warm appreciation also goes to my parents, En. Ismail bin Saad and Pn. Siti Mariam bt Abdullah, my parent in law, my siblings and other family members for all their endless prayers and thought that motivate me to finish this research. Not forgetting my special acknowledgement to all my colleagues namely Muhammad Safwan, Siti Rohana, Nor Shahida, Siti Shuhadah, Siti Salwa, Zaid, Emee Marina, Rohani, Fahmin, and Azlina for the encouragement, company, and fruitful interaction over my study period.

Not to forget a lot of thanks goes to the University Sains Malaysia under Postgraduate Research Grant Scheme (PBAHAN/1001/8044036) and the Malaysia Ministry of Higher Education under MyBrain15 (MyPhD) for financial support and

scholarship for my study. Sincere thanks to the School of Materials and Mineral Resources Engineering (SMMRE) and School of Electrical and Electronic Engineering (SEEE), Universiti Sains Malaysia (Engineering Campus) for providing me the facilities to carry out my research work. I am also thankful to all staff in SMMRE and SEEE for their cooperation and help to complete this research work.

## TABLE OF CONTENTS

Acknowledgement .....	ii
Table of Contents .....	iv
List of Tables .....	xi
List of Figures .....	xiii
List of Abbreviations .....	xix
List of Symbols .....	xxi
Abstrak .....	xxiii
Abstract .....	xxv

### CHAPTER 1 - INTRODUCTION

1.1 Overview .....	1
1.2 Problem statement .....	3
1.3 Research objectives .....	6

### CHAPTER 2 - LITERATURE REVIEW

2.1 Historical development of polymeric insulators for high voltage .....	7
2.1.1 Construction and types of polymeric insulators.....	9
2.2 Development of thermoplastic elastomer for high voltage insulation application.....	14
2.2.1 Thermoplastic elastomer .....	14
2.2.2 Various investigations on the thermoplastic elastomer for high voltage insulators .....	16
2.2.2.1 Polyethylene based thermoplastic elastomers.....	17

2.2.2.2	Silicone rubber based thermoplastic elastomers .....	21
2.3	Application of micro and nano-size filler to improve performance of high voltage insulators .....	25
2.4	Properties of nanocomposites for high voltage insulator .....	28
2.4.1	Dielectric spectroscopy (Permittivity and loss tangent) .....	29
2.4.1.1	Nanocomposite dielectric concepts.....	32
2.4.2	Dielectric breakdown strength .....	34
2.4.2.1	Breakdown behavior in polymer nanocomposites .....	37
2.4.3	Mechanical properties .....	39
2.4.4	Surface hydrophobicity .....	41
2.5	Factors controlling the properties of thermoplastic elastomer nanocomposite .....	43
2.5.1	Phase morphology.....	44
2.5.2	Types and characteristics of nanofillers.....	46
2.5.3	Nanofiller loading .....	48
2.5.4	Thermoplastic-rubber blend ratio.....	52
2.6	Processing of thermoplastic elastomer nanocomposites .....	54
2.6.1	Melt blending .....	54
2.6.2	Electron beam irradiation crosslinking .....	55
2.7	Previous research on thermoplastic elastomer nanocomposites in electrical insulation field .....	57
2.8	Ageing of polymeric insulators .....	61
2.8.1	Ultraviolet ageing.....	61
2.8.2	Heat ageing .....	63
2.8.3	Water ageing .....	64

2.9	Parameters optimization by using design of experiment.....	64
2.9.1	Application of design of experiments for the optimization of thermoplastic elastomer nanocomposites.....	67
2.10	Summary.....	69

## CHAPTER 3 - MATERIALS AND METHODS

3.1	Overview .....	71
3.2	Raw materials .....	72
3.2.1	Linear low density polyethylene and silicone rubber .....	72
3.2.2	Nanofillers.....	73
3.3	Solvents .....	73
3.4	Methodology.....	73
3.4.1	Effect of mixing sequences .....	74
3.4.2	Design of experiments for optimization of LLDPE/SR nanocomposites .....	76
3.4.3	Effect of electron beam irradiation crosslinking.....	78
3.4.4	Effect of various ageing types.....	80
3.5	Characterization techniques.....	81
3.5.1	Particle size analysis .....	81
3.5.2	Specific surface area analysis .....	82
3.5.3	Measurement of swelling and crosslink density .....	82
3.5.4	Measurement of dielectric breakdown strength .....	83
3.5.5	Measurement of dielectric spectroscopy .....	85
3.5.6	Measurement of volume resistivity.....	86

3.5.7	Measurement of contact angle for hydrophobicity	
	determination .....	87
3.5.8	Measurement of contact angle for surface tension	
	determination .....	88
3.5.9	Measurement of tensile properties .....	90
3.5.10	Morphology observation .....	91
3.5.11	Differential scanning calorimetry .....	91
3.5.12	Measurement of rheological properties.....	92
3.5.13	Fourier transform infrared spectroscopy .....	93

## **CHAPTER 4 - RESULTS AND DISCUSSION**

4.1	Overview .....	94
4.2	Part 1: Effect of mixing sequences .....	94
4.2.1	The formation of LLDPE/SR/BN phase structures.....	95
4.2.2	Differential scanning calorimetry .....	100
4.2.3	Permittivity and loss tangent.....	102
4.2.4	Dielectric breakdown strength .....	107
4.2.5	Volume resistivity .....	112
4.2.6	Tensile properties .....	114
4.2.7	Contact angle .....	118
4.2.8	Summary .....	119
4.3	Part 2: Statistical designs and optimization of formulation	
	parameters of LLDPE/SR nanocomposites .....	120
4.3.1	Preparation of LLDPE/SR nanocomposites by using	
	three-level factorial design.....	121



4.3.2	Development of regression model equations .....	124
4.3.3	Model adequacy checking.....	126
4.3.3.1	$R^2$ test .....	126
4.3.3.2	ANOVA .....	129
4.3.4	Interactions of design parameters and their effects on the properties of LLDPE/SR nanocomposites .....	132
4.3.4.1	Permittivity .....	132
4.3.4.2	Loss tangent .....	134
4.3.4.3	Dielectric breakdown strength .....	136
4.3.4.4	Volume resistivity .....	141
4.3.4.5	Tensile strength .....	143
4.3.4.6	Tensile modulus .....	147
4.3.4.7	Elongation at break .....	149
4.3.5	Optimization of LLDPE/SR nanocomposites .....	151
4.3.6	Summary .....	155
4.4	Part 3: Effect of electron beam irradiation crosslinking on LLDPE/SR/BN nanocomposites .....	156
4.4.1	Swelling and crosslink density.....	156
4.4.2	Morphology.....	160
4.4.3	Rheological study on irradiation crosslinked LLDPE/SR/BN nanocomposites.....	162
4.4.3.1	Strain sweep .....	163
4.4.3.2	Frequency sweep.....	166
4.4.4	Permittivity and loss tangent.....	169
4.4.5	Dielectric breakdown strength .....	172

4.4.6	Volume resistivity .....	175
4.4.7	Tensile strength and modulus .....	177
4.4.8	Elongation at break .....	179
4.4.9	Contact angle .....	180
4.4.10	Summary .....	181
4.5	Part 4: Effect of various ageing types on insulation performance of LLDPE/SR/BN nanocomposites .....	182
4.5.1	Ultraviolet ageing.....	183
4.5.1.1	Fourier transform infrared spectroscopy.....	183
4.5.1.2	Permittivity and loss tangent.....	185
4.5.1.3	Dielectric breakdown strength .....	187
4.5.1.4	Contact angle .....	190
4.5.2	Heat ageing .....	192
4.5.2.1	Fourier transform infrared spectroscopy.....	192
4.5.2.2	Permittivity and loss tangent.....	193
4.5.2.3	Dielectric breakdown strength .....	196
4.5.2.4	Contact angle .....	197
4.5.3	Water ageing .....	199
4.5.3.1	Permittivity and loss tangent.....	199
4.5.3.2	Dielectric breakdown strength .....	202
4.5.3.3	Contact angle .....	205
4.5.4	Summary .....	207

## **CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS**

5.1	Conclusions .....	209
-----	-------------------	-----

5.2	Recommendations .....	211
-----	-----------------------	-----

<b>REFERENCES</b> .....	214
-------------------------	-----

## **APPENDICES**

## **LIST OF PUBLICATIONS**

## LIST OF TABLES

		<b>Page</b>
Table 2.1	Voltage classification according to IEC 60038 (Agrawal, 2007)	8
Table 2.2	Previous research works on various polymer based materials for electrical insulation	12
Table 2.3	Silicone rubber classification according to ASTM D1418-05 (Ramirez, 2009)	22
Table 2.4	Role of most common inorganic fillers used in dielectric applications (Momen and Farzaneh, 2011; Huang et al., 2011)	26
Table 2.5	List of dielectric strengths of insulating polymers (Naidu and Kamaraju, 2004)	34
Table 2.6	List of the publications dealing with thermoplastic elastomer systems comprising nanofillers for electrical insulation applications	59
Table 3.1	The characteristics of nanofillers used in the study	73
Table 3.2	Formulation of LLDPE/SR nanocomposites by varying the mixing sequences	76
Table 3.3	Variables in three-level factorial design	77
Table 3.4	The three-level factorial design for the preparation of LLDPE/SR nanocomposites	78
Table 4.1:	Contact angle and surface tension results of LLDPE, SR and BN nanofillers	97
Table 4.2:	The value of interfacial tension of LLDPE/SR/BN nanocomposites	97
Table 4.3:	Summary of DSC data of the LLDPE/SR blend and its nanocomposites	102
Table 4.4	Scale and shape parameter of LLDPE/SR and its nanocomposites	108
Table 4.5	Three-level factorial design experiments with responses (uncoded)	122

Table 4.6	Results from $R^2$ test	127
Table 4.7	Summary of ANOVA results for various responses of LLDPE/SR nanocomposites	131
Table 4.8	Constraints applied for optimization	152
Table 4.9	Solutions of formulation parameters optimization of LLDPE/SR nanocomposites with the optimum responses and desirability indices	154
Table 4.10	Comparison of properties between experimental and predicted by the regression equations	154
Table 4.11	Scale and shape parameter of unirradiated and irradiated LLDPE/SR/BN nanocomposites	174
Table 4.12	Dielectric breakdown strength (Weibull scale parameter) and its retention of unirradiated and irradiated LLDPE/SR/BN nanocomposites on the effect of UV ageing	189
Table 4.13	Dielectric breakdown strength (Weibull scale parameter) and its retention of unirradiated and irradiated LLDPE/SR/BN nanocomposites on the effect of heat ageing	197
Table 4.14	Dielectric breakdown strength (Weibull scale parameter) and its retention of unirradiated and irradiated LLDPE/SR/BN nanocomposites on the effect of water ageing	203

## LIST OF FIGURES

		<b>Page</b>
Figure 2.1	Advantages and disadvantages of polymeric insulators (Hackam, 1999)	9
Figure 2.2	Components of composite suspension insulator (Ramirez, 2009)	10
Figure 2.3	(a) Torsional load suspension insulator; (b) Tensile load suspension insulator; (c) Post insulator (Sharma, 2001)	11
Figure 2.4	Chemical structure of thermoplastic elastomer (Amin and Salman, 2011)	15
Figure 2.5	Chemical structure of polydimethylsiloxane (PDMS) (Momen and Farzaneh, 2011)	22
Figure 2.6	Illustration of how the ratio of particle to interaction zone is changing due to a reduction of the particle size (Andritsch et al., 2010)	28
Figure 2.7	Four main polarizations from lower to higher frequency (Hussin, 2011)	30
Figure 2.8	The frequency dependence of permittivity and loss tangent in the presence of interfacial, orientational, ionic and electronic polarization mechanisms (Loftness, 1952)	32
Figure 2.9	Variation of breakdown strength with time after application of voltage (Naidu and Kamaraju, 2004)	36
Figure 2.10	Schematic depiction of morphology of (a) LDPE/EVA, (b) LDPE/EVA/SiO <sub>2</sub> prepared by two-step mixing and (c) LDPE/EVA/SiO <sub>2</sub> prepared by one-step mixing (Hui et al., 2010b)	46
Figure 2.11	Breakdown strength in ceramic materials decreases with increasing dielectric constant (Tan et al., 2007)	47
Figure 2.12	Possible nature of charge transfer mechanism in nanocomposites at (a) low nanofiller loading and (b) high nanofiller loading (Preetha and Thomas, 2011)	49
Figure 2.13	Schematic diagram of overlapped interaction zone around nanoparticles when nanofiller exceed percolation threshold (Chen et al., 2009)	50

Figure 2.14	SEM micrographs of toluene extracted surface containing (a) 70:30 (b) 50:50 and (c) 30:70 LLDPE:PDMS proportion (Giri et al., 2012a)	53
Figure 2.15	Experimental designs based on the study of all variables in three levels: three-level factorial design for the optimization of (a) two variables and (b) three variables and (c) Box–Behnken design for the optimization of three variables (Bezerra et al., 2008)	66
Figure 3.1	General framework of the research parts	72
Figure 3.2	Schematic illustration representing the preparation of LLDPE/SR/BN nanocomposites by means of electron beam irradiation	79
Figure 3.3	Set-up for dielectric breakdown test	85
Figure 3.4	Breakdown voltage tester	85
Figure 3.5	Volume resistivity measurement system (Ehsani et al., 2004a)	86
Figure 3.6	Two extreme examples of contact angles	88
Figure 3.7	Contact angle measurement set up	88
Figure 4.1	SEM micrographs of (a) 70/30; (b) 70/30/5BN-S1; (c) 70/30/5BN-S2; and (d) 70/30/5BN-S3	99
Figure 4.2	HRTEM image of SR encapsulated BN in 70/30/5BN-S2 nanocomposite system	100
Figure 4.3	DSC crystallization exotherms of LLDPE/SR/BN nanocomposites prepared by different mixing sequences	101
Figure 4.4	Frequency dependency of $\epsilon'$ of unfilled LLDPE/SR and LLDPE/SR/BN nanocomposites prepared by different mixing sequences	104
Figure 4.5	Frequency dependency of $\tan \delta$ of unfilled LLDPE/SR and LLDPE/SR nanocomposites prepared by different mixing sequences	106
Figure 4.6	Weibull plot of DBS of LLDPE/SR blend and its nanocomposites prepared by different processing methods	108
Figure 4.7	Volume resistivity of LLDPE/SR and its nanocomposites prepared by different mixing sequences	113

Figure 4.8	Tensile strength and tensile modulus of LLDPE/SR blend and its nanocomposites prepared by different mixing sequences	115
Figure 4.9	Elongation at break of LLDPE/SR blend and its nanocomposites prepared by different mixing sequences	118
Figure 4.10	Contact angle of LLDPE/SR blend and its nanocomposites prepared by different mixing sequences	119
Figure 4.11	Predicted versus experimental for (a) permittivity; (b) loss tangent; (c) dielectric breakdown strength; (d) volume resistivity	128
Figure 4.12	Three-dimensional response surface plots of permittivity as a function of silicone rubber content and nanofiller loading for (a) Si, (b) BN, and (c) ZO filled LLDPE/SR nanocomposites	133
Figure 4.13	Three-dimensional response surface plots of loss tangent as a function of silicone rubber content and nanofiller loading for (a) Si, (b) BN, and (c) ZO filled LLDPE/SR nanocomposites	135
Figure 4.14	Three-dimensional response surface plots of dielectric breakdown strength as a function of silicone rubber content and nanofiller loading for (a) Si, (b) BN, and (c) ZO filled LLDPE/SR nanocomposites	137
Figure 4.15	SEM image showing the presence of nano-Si at the vicinity of the etched SR phase in 90/10/5 LLDPE/SR/Si nanocomposite (can be observed in circled area). The insert image indicate the area that has been magnified	139
Figure 4.16	Three-dimensional response surface plots of volume resistivity as a function of silicone rubber content and nanofiller loading for (a) Si, (b) BN, and (c) ZO filled LLDPE/SR nanocomposites	142
Figure 4.17	Three-dimensional response surface plots of tensile strength as a function of silicone rubber content and nanofiller loading for (a) Si, (b) BN, and (c) ZO filled LLDPE/SR nanocomposites	144
Figure 4.18	SEM image of toluene etched fractured surfaces of 90/10/2 LLDPE/SR/ZO nanocomposite	146
Figure 4.19	TEM micrographs of 90/10/2 LLDPE/SR/ZO nanocomposite showing ZO nanoparticles inside SR domains at (a) low and (b) high magnification	147



Figure 4.20	Three-dimensional response surface plots of tensile modulus as a function of silicone rubber content and nanofiller loading for (a) Si, (b) BN, and (c) ZO filled LLDPE/SR nanocomposites	148
Figure 4.21	Three-dimensional response surface plots of elongation at break as a function of SR content and nanofiller loading for (a) Si, (b) BN, and (c) ZO filled LLDPE/SR nanocomposites	150
Figure 4.22	Variation of percentage of swelling and crosslink density of LLDPE/SR/BN nanocomposites with the electron beam irradiation doses	157
Figure 4. 23	Schematic diagram of crosslinking reaction of LLDPE and SR under EB irradiation	159
Figure 4.24	SEM micrograph of cryofractured surfaces of LLDPE/SR/BN nanocomposites after etching, irradiated at (a) 0 kGy; (b) 20 kGy; (c) 50 kGy, and (d) 100 kGy	161
Figure 4.25	Effect of shear-strain amplitude on the $G'$ of unirradiated and irradiated LLDPE/SR/BN nanocomposites at varied irradiation dose	164
Figure 4.26	Schematic representation of possible structure developed in crosslinked TPEs illustrating difference in the domain size and matrix/domain interaction of the TPEs irradiated at two different doses: (a) 50 kGy; (b) 100 kGy	165
Figure 4.27	Joint shell model shows the adsorption of LLDPE molecular chains or polymer segments on the surface of crosslinked SR domains (Babu et al., 2010)	165
Figure 4.28	Effect of EB irradiation doses on the frequency dependence of (a) complex viscosity and (b) storage modulus of LLDPE/SR/BN nanocomposites	167
Figure 4.29	Frequency dependency of (a) $\epsilon'$ and (b) $\tan \delta$ of LLDPE/SR/BN nanocomposites irradiated at different doses	171
Figure 4.30	Weibull plot of dielectric breakdown strength of LLDPE/SR/BN nanocomposites irradiated at different doses	173
Figure 4.31	Variation in volume resistivity of LLDPE/SR/BN nanocomposites irradiated at different doses	176

Figure 4.32	Variation in tensile strength and tensile modulus of LLDPE/SR/BN nanocomposites irradiated at different doses	178
Figure 4.33	Variation in elongation at break of LLDPE/SR/BN nanocomposites irradiated at different doses	179
Figure 4.34	Variation in contact angle of LLDPE/SR/BN nanocomposites irradiated at different doses	181
Figure 4.35	Colour changes in the nanocomposite samples before and after UV ageing for 300, 700 and 1000 hours	184
Figure 4.36	Fourier transform infrared spectroscopy spectra of LLDPE/SR/BN nanocomposites before and after UV ageing	185
Figure 4.37	Frequency dependency of (a) $\epsilon'$ and (b) $\tan \delta$ of unirradiated and irradiated LLDPE/SR/BN nanocomposites on the effect of UV ageing	186
Figure 4.38	Effect of UV ageing on dielectric breakdown strength of unirradiated and irradiated LLDPE/SR/BN nanocomposites	189
Figure 4.39	Effect of UV ageing on contact angle and its retention of unirradiated and irradiated LLDPE/SR/BN nanocomposites	191
Figure 4.40	Fourier transform infrared spectroscopy spectra of LLDPE/SR/BN nanocomposites before and after heat ageing	193
Figure 4.41	Frequency dependency of (a) $\epsilon'$ and (b) $\tan \delta$ of unirradiated and irradiated LLDPE/SR/BN nanocomposites on the effect of heat ageing	195
Figure 4.42	Effect of heat ageing on dielectric breakdown strength of unirradiated and irradiated LLDPE/SR/BN nanocomposites	197
Figure 4.43	Effect of heat ageing on contact angle and its retention of unirradiated and irradiated LLDPE/SR/BN nanocomposites	198
Figure 4.44	Frequency dependency of (a) $\epsilon'$ and (b) $\tan \delta$ of unirradiated and irradiated LLDPE/SR/BN nanocomposites on the effect of water ageing	201

Figure 4.45	Effect of water ageing on dielectric breakdown strength of unirradiated and irradiated LLDPE/SR/BN nanocomposites	203
Figure 4.46	Effect of water ageing on contact angle and its retention of unirradiated and irradiated LLDPE/SR/BN nanocomposites	206

## LIST OF ABBREVIATIONS

AC	Alternating current
ANOVA	Analysis of variance
ATR	Attenuated total reflectance
BN	Boron nitride
CCD	Charge-coupled camera device
DBS	Dielectric breakdown strength
DC	Direct current
DCP	Dicumyl peroxide
DOE	Design of experiment
DSC	Differential scanning calorimetry
EB	Electron beam
EPDM	Ethylene propylene diene monomer
EPR	Ethylene propylene rubber
EVA	Ethylene vinyl acetate
FTIR	Fourier transform infrared
HRTEM	High-resolution transmission electron microscopy
HTV	High-temperature vulcanized
HV	High voltage
IEC	International Electrotechnical Commission
LDPE	Low density polyethylene
LLDPE	Linear low density polyethylene
LMW	Low molecular weight
OFAT	One factor at a time

PDMS	Polydimethylsiloxane
PE	Polyethylene
PP	Polypropylene
RSM	Resonance surface methodology
RTV	Room-temperature vulcanized
S1	Sequence 1
S2	Sequence 2
S3	Sequence 3
SEM	Scanning electron microscopy
Si	Silica
SR	Silicone rubber
TPE	Thermoplastic elastomer
UV	Ultraviolet
VMQ	Vinyl methyl quality
XLPE	Crosslinked polyethylene
ZO	Zinc oxide

## LIST OF SYMBOLS

$\Delta H_f$	Melting enthalpy
$G'$	Storage modulus
$h$	Hours
$kGy$	Kilogray
$kV$	Kilovolt
$kV/mm$	Kilo volt per milimeter
$MeV$	Megaelectron-volts
$MPa$	Megapascal
$V_p$	Peak-to-peak voltage
$R^2$	Correlation coefficient
$V_{rms}$	Root mean square voltage
$\tan \delta$	Dielectric loss tangent
$T_g$	Glass transition temperature
$T_{pc}$	Crystallization peak temperature
$vol\%$	Volume percent
$W_a$	Wetting coefficient
$W_{AB}$	Work of adhesion
$wt\%$	Weight percent
$X_c$	Percentage of crystallinity
$\alpha$	Weibull scale parameter
$\beta$	Weibull shape parameter
$\gamma$	Surface tension
$\gamma_{AB}$	Interfacial tension

$\gamma_c$	Critical strain
$\gamma^d$	Dispersion component surface tension
$\gamma^p$	Polar component surface tension
$\varepsilon'$	Permittivity
$\eta^*$	Complex viscosity
$\omega$	Frequency

**SIFAT- SIFAT KOMPOSIT NANO POLIETILINA BERKETUMPATAN  
RENDAH LINEAR/GETAH SILIKON UNTUK APLIKASI PENEBAK  
BERVOLTAN TINGGI**

**ABSTRAK**

Kajian ini menyiasat prestasi komposit nano termoplastik elastomer berasaskan campuran polietilena berketumpatan rendah linear (LLDPE) dan getah silikon (SR) diisi dengan pelbagai jenis pengisi nano bukan organik seperti silika (Si), boron nitrida (BN) dan zink oksida (ZO) untuk aplikasi penebat bervoltan tinggi. Bahagian pertama kajian menyiasat kesan urutan pencampuran yang berbeza pada sifat-sifat komposit nano LLDPE/SR/BN. 5 vol% nano-BN telah dimasukkan ke dalam 70/30 LLDPE/SR dengan menggunakan tiga urutan yang berbeza; LLDPE + SR + BN (dicampur dalam satu langkah pemprosesan), LLDPE + (masterbatch-SR/BN) dan SR + (masterbatch-LLDPE/BN), di mana sampel-sampel dengan masterbatch disediakan dalam dua langkah pemprosesan. Sampel dengan masterbatch-SR/BN mempamerkan struktur pengkapsulan dan menunjukkan kekuatan pecahan dielektrik yang tertinggi dan ketelusan serta kehilangan tangen yang paling rendah berbanding dengan dua urutan pencampuran yang lain yang menjana struktur penyebaran terpisah. Kemudian, dengan menggunakan urutan pencampuran yang optimum, pelbagai jenis komposit nano LLDPE/SR telah disediakan. Kesan tiga formulasi parameter seperti kandungan SR (10, 20 dan 30 wt%), jenis pengisi nano (Si, BN dan ZO) dan kandungan pengisi nano (2, 5 dan 8 vol%) terhadap sifat-sifat komposit nano LLDPE/SR telah disiasat secara statistik dengan menggunakan reka bentuk eksperimen (DOE). Berdasarkan analisis DOE, didapati bahawa komposit nano